OBSERVATIONS OF THE APPARENT EFFECTS OF AIRPLANE SPRAYED DDT UPON FISH AND WILDLIFE IN THE TUOLUMNE MEADOWS AREA, YOSEMITE NATIONAL PARK, CALIFORNIA

SEPTEMBER 15 - 19, 1953.

Orthello L. Wallis,
Park Ranger

Introduction

The last great infestation of needleminer in the lodgepole pine forests of the Tuolumne Meadows-Tenaya Lake Area of Yosemite National Park occurred between 1912 and 1922. Thousands of trees in an area of approximately 30,000 acres were killed during this epidemic. The dead trees were so numerous and conspicuous that the area west of Tuolumne Meadows became known as the "Ghost Forest."

The most recent infestation which has infiltrated into this general area during the past several years has now reached epidemic proportions. The new lodgepole pine forests, which have sprung up in the "Ghost Forest," as well as the surrounding forests are endangered by this new outburst of the needleminer.

Other areas within the park, as well as the Tuolumne Meadows-Tenaya Lake area, are likewise threatened by the advance of this insect. These areas were mapped and studied from the air by Park Forester Emil Ernst during the October 21, 1952 aerial reconnaissance flight. They include all of the lodgepole pine type forests of the northeastern portion of the park from the Matterhorn to the summit of the Sierra Nevada and the forests of the upper Jack Main Canyon, Rodgers Canyon below Neall Lake, and west of Pleasant Valley.

The National Park Service has been working in cooperation with the U. S. Bureau of Entomology and Plant Quarantine in attempting to determine possible measures to control this most recent outburst. Earlier, during 1935, CCC crews were employed to combat an epidemic in the Porcupine Flat Area with the use of Naptha base insecticides. More recently, the employment of a helicopter to disperse insecticides in the Tenaya Lake Area in August 1949 proved unsuccessful because of hazardous flying conditions. Forty acres were sprayed from the air with benzine-hexachloride (BHC) and 20 acres were treated with dichloro-diphenyl-trichloroethane (DDT) before the helicopter operation was terminated. An additional 5 acres were sprayed with DDT and 1 acre with BHC by ground spraying equipment.

To combat the present needleminer epidemic, it was agreed that an experimental attempt to spray about 11,000 acres of the 46,000 acres of affected forests within the park should be undertaken from a conventional type airplane during the summer of 1953. This area would be in the vicinity of Tuolumne Meadows and Tenaya Lake because of its high scenic value to thousands of visitors who travel the Tioga Road.

The Lodgepole Pine Needleminer, Recurvaria milleri Busck, is the cause of the alarm. The larvae kill the needles of the lodgepole pine and often completely defoliate the trees. As a direct result of this defoliation or because of the secondary attacks of the injuried trees by the mountain pine beetle, the lodgepole pines are killed in great numbers. This insect requires two years in which to complete its life cycle. 1953 was the flight year when the adults emerge from the needles and lay the eggs of the next generation. Spraying operations to obtain maximum effectiveness must be timed to kill the young larvae as they emerge from the eggs and make their way to the initial feeding points.

In this new attempt to halt the needleminer, the insecticide, DDT, was used. It was applied at the rate of 1 lb. DDT in 1 gallon of oil per acre. DDT has provided control for other forest insects although never conclusively proven effective against the needleminer.

Shortly after the announcement that DDT would be sprayed over the forests in the Tuolumne Meadows Area, a certain amount of concern was expressed about the possible effects of this powerful insecticide upon the fish and wildlife organisms within the treated area.

On June 17, 1953, Chief Biologist Victor Cahalane, Park Forester Ernst, Administrative Assistant Robert McIntyre and I looked over a portion of the infected area along the Tioga Road above Tenaya Lake. It was Mr. Cahalane's opinion that definite study should be made of the effects of the DDT spraying upon the fish and wildlife forms. Chief Naturalist John Doerr and Regional Naturalist Dorr Yeager agreed with this opinion during their visit to the park during early July. Therefore, in accorance with the Regional Director's memorandum (N 16) of July 22, 1953, definite plans were made to check the possible effects of the DDT spraying upon the fish and wildlife of the Tuolumne Meadows-Tenaya Lake Area.

This report will cover the observations made after the spraying operations had taken place. It had been hoped that these observations would be more extensive but a series of events prohibited this. Because of the late development of the insects this summer, the actual spraying operations were poseponed several times and did not occur until mid-September, at which time the park was experiencing the worst series of fires in its history.

Spraying Operations

The actual spraying operations occurred between September 15 and 19, 1953. During this period, the DDT was sprayed from a B-17 airplane at the rate of 1 lb. DDT in one gallon of diesel per acre over the area of approximately 11,000 acres. The portion of the park covered roughly extended from Ragged Peak southwestward through the Dingley and Delaney Creek basins, across the western end of Tuolumne Meadows to Tenaya Lake and included the Lower Cathedral Lake basin. The insecticide was applied at heights as low as 50 feet above the trees.

The personnel of the Bureau of Entomology and Plant Quarantine (Division of Forest Insects) supervised the operations. They distributed about 500 chemically treated cards — about one card for every 20 acres — over the area sprayed. From these cards, it was possible for them to estimate the distributation and the amount of spray applied. In the recent letter of October 29, 1953 from Dr. R. C. Hall, the survey leader, he stated that "these cards showed a remarkably uniform coverage of the 11,000 acres sprayed and in no case did there appear any spots which had been covered too heavily. Our cards showed a recovery of about one-half pound per acre which is about normal."

Observations of the Apparent Effects Upon Fish and Wildlife

Mr. Hall, Park Forester Ernst & Mr. David Todd, Seasonal Aid for the Bureau of Entomology and Plant Quarantine, made observations in the Tuolumne Meadows-Tenaya Lake Area during the spraying operations and shortly thereafter. These observations were made at a number of the lakes and in some of the streams. On September 19, District Ranger Walter Gammill made investigations at Tenaya Lake. Mr. McIntyre and I visited several lakes on September 20.

TENAYA LAKE OBSERVATIONS. A few reports of dead fish along the shores of Tenaya Lake began to come into the park headquarters toward the end of the week of spraying operations. On Saturday, September 19, 1953, Mr. Gammill stopped at Tenaya Lake to investigate these reports.

At 9 A. M., he discovered 107 Sacramento suckers, 4 to over 12 inches in length, 60 trout, mostly about 3 inches, and one frog dead along the lower end of the lake. One 6 inch sucker and two 3 inch trout were still alive but "very sick." A few dead trout were found near the mouth of Murphy Creek. At the upper end of Tenaya Lake, from the road to the spring, he counted the following dead fish: 18 suckers, 4 to 12 inches long, and 68 fingerling trout. Bear tracks indicated that a portion of the fish kill had been salvaged by these animals.

The preceeding afternoon, Forester Ernst and Mr. Todd counted 31 suckers and 104 fingerling trout along the upper shoreline. Later in the afternoon, Mr. Todd discovered an additional 29 suckers and 98 trout along the shore beside the Tioga Road.

About noon on September 20, I walked completely around Tenaya Lake anc counted and measured every dead fish I found. When Mr. McIntyre returned from his investigations at Polly Dome Lakes, he counted the dead fish along a half mile section of the shoreline below Murphy Creek. A total of 275 trout and 283 suckers were counted by us. Some affected suckers were still alive but were in convulsions and lying on their sides.

Of the dead trout counted, 79 percent or 218 fish averaged 3 inches in total length. Those measuring less than 3 to 4 inches amounted to 96 percent of the total dead trout. Some of the dead trout which were larger than 3 inches were in an advanced state of decomposition and obviously had died even before the DDT spraying had begun. During the late summer, it is not unusual to observe a few dead trout along the shores of most of our lakes. Usually these summer-killed fish are the larger mature fish. All of the smaller trout were rainbow trout; several of the larger ones were brown trout.

Although a few small dead suckers were found, the greatest proportion of the dead fish of this species measured between 9 and 13 inches with an average total length between 10 and 11 inches.

Fresh bear and coyote tracks also were observed in the wet sands along the shorelines. A large number of gulls, as many as 32 at one time, were found actively feeding on the surface of the lake or along the shores. It was evident that our counts did not include all of the fish which had been killed as a direct result of the DDT spraying. These scavangers had undoubtedly eaten many of the dead or dying fish.

No other forms of animal life were found dead or affected along the shores of Tenaya Lake.

From these observations, it is evident that the DDT apparently has its greatest effects upon the fish which were in the shallow waters. The adult suckers and the small trout feed extensively in this portion of the lake.

The destruction of this number of fish in Tenaya Lake is regrettable but is not alarming. It had been estimated by some individuals that the kill would be even greater. Neither the trout nor the sucker populations are native to this body of water. Probably, the suckers were introduced initially in 1878 together with the first trout which had been seined from the lower stretches of the Tuolumne River. The sucker is also plentiful in these waters and could well have been seined out along with the trout. The trout population is maintained by annual stocking. On July 31, 1953, 35,520 rainbow trout fingerlings, measuring 74 fish per ounce, were released into Tenaya Lake. The bulk of the dead trout, those under 3 to 4 inches, was made up of fish from this planting.

The area of Tenaya Lake approximates 150 acres as determined by baseline:aerial photograph measurements and calculations.

A tabulation of the count of the dead or dying fish observed along the shores of Tenaya Lake is found on the accompanying table.

A TABULATION OF THE NUMBERS OF TROUT AND SUCKERS WHICH WERE FOUND DEAD ON THE SHORES OF TENAYA LAKE APPARENTLY AS THE DIRECT RESULT OF THE AERIAL SPRAYING OF DDT IN OIL MIXTURE, SEPTEMBER 15 - 19, 1953.

TOTAL LENGTH	NORTH SHORE		EAST SHORE		SOUTH SHORE		WEST SHORE		TOTAL FISH FOUND			
Groups (in Inches)	No. of Suckers	No. of Trout	No. of Suckers	No. of Trout	No. of Suckers	No. of Trout	No. of Suckers	No. of Trout	No. of Suckers	% of Total	No. of Trout	% of Total
September 20 (12:15 - 2:50 P.M.) O. L. Wallis and R. N. McIntyre												
2-3	—	12	—	7	—	4	—	21	—	—	44	16%
3-4	—	68	1	18	—	44	2	88	3	1.1%	218	79%
4-5	—	—	—	—	1	1	1	—	2	0.7%	1	0.3%
5-6	2	—	3	—	1	—	3	1	9	3.2%	1	0.3%
6-7	—	—	3	1	—	1	4	—	7	2.5%	2	0.7%
7-8	—	1	1	1	1	—	1	—	3	1.1%	2	0.7%
8-9	—	—	4	1	5	—	11	1	20	7.0%	2	0.7%
9-10	9	1	9	1	18	2	23	—	59	20.8%	4	1.5%
10-11	3	—	8	—	34	—	38	—	83	29.0%	-	—
11-12	2	—	7	—	17	—	16	1	42	14.8%	1	0.3%
12-13	5	—	7	—	15	—	8	—	35	12.4%	-	—
13-14	—	—	4	—	6	—	2	—	12	4.2%	-	—
14-15	1	—	1	—	4	—	2	—	8	2.8%	-	—
TOTALS	22	82	48	29	102	52	111	112	283	SUCKERS	275	TROUT

DOG LAKE OBSERVATIONS Along the shores of Dog Lake, I counted and measured a total of 234 dead or dying eastern brook trout on September 20, 1953 between 9:15 and 10:30 A.M. This was several days after the spraying of this area had occurred. As in the case of the trout in Tenaya Lake, the majority of the dead fish were found to be in the 3 inch group. Two fish were still alive but definitely affected and near death. Most of the trout, however, had been dead for a day or more; only a few appearred relatively freshly killed.

A large number of apparently healthy 3 inch trout were found actively feeding in the shallow portions of the lake.

The count of the dead fish in this lake as in Tenaya Lake does not indicate the total number of trout which had been killed. Several factors made it impossible to make a complete count. Various scavangers had eaten many of the fish. Seventeen gulls were actively feeding on the lake while I was making my investigations. Bear and coyote tracks along the shorelines indicated that these animals had been patrolling the shores and eating the dead fish. The wind and wave action had buried many small trout under logs, in the organic debris and sand, or under the overhanging banks. Under one log, I rolled over, I counted 17 dead trout fingerlings. The wind which was blowing had roiled up the water so that it was difficult to observe the dead fish on the bottom of the lake for more than a short distance from the shore.

Several dead giant water beetles and adult dragonflies were observed.

Although Dog Lake is only about 31 acres in extent or about one-fifth the size of Tenaya Lake, the dead trout counted at each lake was nearly equal. The proportion of relatively shallow water in Dog Lake is greater and undoubtedly accounted for the proportionately greater loss of trout in this lake. The trout population in Dog Lake is not native and is maintained by annual plantings. On August 3, 1953, 25,098 eastern brook trout fingerlings had been planted here. The majority of the dead fish originated from this stocking.

LOWER CATHEDRAL LAKE OBSERVATIONS. The loss of trout in Lower Cathedral Lake was very light. On September 20, Mr. Todd found 21 dead eastern brook trout; 14 of them were under 6 inches. The average length of the fish was about 5 inches, a somewhat larger size than usual. This lake covers about 12 acres. Annual plantings maintain the non-native trout population; 7,020 fingerlings were planted on August 4, 1953.

ELIZABETH LAKE OBSERVATIONS. Mr. Todd visited Elizabeth Lake on September 18, 1953. He discovered 87 dead eastern brook trout, 4 dead frogs and a number of dead giant water beetles and dragonflied. Seventy-seven of the trout measured less than 6 inches. Along the trail to the lake, he found large numbers of ants and bees which were affected and dying as the result of the DDT spraying operations. Elizabeth Lake fishing is supported by periodic stocking. The last plant was made on August 17, 1953 when 7,000 eastern brook trout fingerlings were stocked. The area of this lake is approximately 24 acres.

POLLY DOME LAKES OBSERVATIONS. Mr. McIntyre visited the four Polly Dome Lakes, west of Polly Dome, on the morning of September 20. These lakes are relatively shallow and contain a considerable amount of organic debris on the bottom. They lie on the fringe of the area which was scheduled for treatment.

No dead fish were found in any of these lakes. Dead frogs were discovered in each lake as follows: Polly Dome Lake: 7; Upper Lake: 19 in shallows and stream bed leading to the Middle Lake; Middle Lake: 9; and Lower Lake: 3. Dead giant water beetles were found in the Middle and Lower Lakes. A few dead dragonflies were also observed.

In each of the lakes, there appeared to be an abundance of alive and apparently unaffected frogs and "tadpoles," and dragonflies. A small number of mallard and shoveler ducks were found on three of the lakes. Other birds were present in usual abundance.

These lakes appeared to have been lightly affected by the spraying operations. Some of the frogs probably died from causes other than the DDT spraying for it is not unusual to find a few dead frogs in various lakes in the late summer.

TUOLUMNE RIVER OBSERVATIONS. Dr. Hall and his associates were unable to discover any dead fish in a one mile stretch of the Tuolumne River in the Tuolumne Meadows which they investigated. My examination of a portion of the river on September 20 did not reveal any dead fish either.

TENAYA CREEK OBSERVATIONS. Five dead fingerling trout were discovered in the landlocked pools of a stretch of the Tenaya Creek by Dr. Hall. The water in these pools in kept cool and refreshed by seepage. This, no doubt, accounts for such a light kill. Because of the crowded conditions in these pools, a heavier mortality was expected than that observed.

Discussion

With regard to the loss of fish in the various lakes, Dr. Hall writes that

> "from our observations we believe that the principle injury to fish was the result of the DDT in oil being concentrated along the edges of the lakes as the result of wind and wave action. For example, we observed practically no injury to small trout in the land-locked pools in Tenaya Creek, where because of the crowded conditions and stagnant water, maximum injury would be expected. This area received the same amount of spray as Tenaya Lake where some injury was observed along the west shore where the DDT residue had been concentrated. As a matter of fact, no spray was applied at the west end of the lake and only a small portion on the east and southeast fringe of the lake was actually sprayed. Our 18 treated cards located near the Tenaya Ranger Station showed no more than normal deposits for that area.
>
> "Collections of DDT residue were made from quiet pools of water at the west edge of Tenaya Lake. This residue has been analysed by Dr. Hoskins of the University of California and he reports that there was a concentration of approximately two pounds of DDT per acre in the samples tested."

It is apparent that when DDT in oil mixture is applied to a portion of the surface area of a large lake, even in normal amounts, the effects upon the fish life depend upon the wind and wave action to a certain extent. A heavy wind and wave action, such as is often present on Tenaya Lake, tends to accumulate the DDT-oil mixture in heavier concentrations along the wave swept shore. This heavier concentration is especially fatal to the fish in the shallow shoreline areas.

This emphasises the fact that special care must be taken to attempt to avoid the spraying of lakes because of the possible stronger concentrations which can accumulate and create greater injury to the fish and aquatic insect life.

From other studies regarding the effects of DDT spraying upon fish life, Brown (1951:728) writes that "the aerial application of 1 lb. DDT per acre, the favoured dosage for forest insect control, is definitely hazardous to fish; but the game fish are less susceptible than the inhabitants of stagnant or exposed pools, and the hazard is less the denser the forest cover."

Adams, et. al. (1949:253) reports that fish such as dace, red-sided shiners, cottoids, suckers, and bullheads were more affected than trout by the applications of DDT in their studies.

The long term, indirect effects of the DDT upon the fish life in the Tuolumne Meadows-Tenaya Lake Area is difficult to estimate. Many investigators has discovered that aquatic insects, one of the main food supplies of the fishes, suffer heavy loss even at application rates of one pound of DDT per acre. (Adams, et. al. 1949:252; Linduska 1950:77; Brown 1951:729)

Linduska (1950:79) reports that "In one pound per acre aerial applications to streams, the fish kill has been nominal but the aquatic insect food of these animals has routinely been reduced by 75 to 90 percent. The results of such marked reductions in essential food items on the survival and growth of fish has not yet been accurately established. However, the rate of recovery among the depleted forms is known to occur rapidly and approaches normal within a year."

EFFECTS UPON BIRDS AND MAMMALS. No apparent effects upon the birds or the mammals of the Tuolumne Meadows-Tenaya Lake Area were observed. Actually no detrimental effects could be expected from the concentrations of the insecticide which was employed. Studies elsewhere have shown that where amounts of less than 1 to 2 pounds of DDT per acre are applied there is little direct danger to bird or animal life. (Linduska, 1950:80; Brown, 1951:723) Large dosages of 5 pounds per acre or over are necessary to cause heavy losses. Birds are especially susceptible in nesting season when they are tied to their territory.

EFFECTS UPON REPTILES AND AMPHIBIANS. A few frogs were the only amphibians which apparently had been affected by the DDT. No affected or dead reptiles were found. Brown (1951:726) reports that frogs are more sensitive to DDT poisoning than warm blooded animals and that generally applications of greater than 1 pound per acre are required to kill snakes, turtles, salamanders, unless they are confined to shallow waters.

FACTORS TO CONSIDER IN APPLYING DDT. The amount of DDT which is applied is a most important determining factor in regulating the extent of the damage to fish and wildlife and for this reason the dosage must be applied evenly and in small enough concentrations to avoid serious damage to fish and wildlife forms. Linduska(1950:79) lists the following other factors which also determine the effects of the insecticide and there for should be taken into consideration and recognized:

1. Wettable DDT powder is less toxic to fish life than emulsions or oil solutions. Oil solutions have the ability to accumulate by wind and wave action.
2. Softer water increases the toxicity of DDT to aquatic forms.
3. Low dissolved oxygen in the water increases the toxicity.
4. Young fish are more susceptible than old.
5. Effectiveness of DDT is dissipated rapidly in running water.
6. Effects of DDT are greatest in clean water of streams and ponds than where the water is muddy or contains organic debris. This is due probably to the establishment of a mechanical bond between the insecticides and foreign materials, an affinity which reduces the toxic effect.
7. Fish provided with an abundance of food survive in greater numbers than fish under partial starvation.

Summary and Conclusions

1. Fish were found dead or dying in Dog, Tenaya, Cathedral, and Elizabeth Lakes. The mortality was greatest among the smaller trout and the larger suckers. The average size of the trout killed was 3 inches as compared with 10-11 inches for the suckers of Tenaya Lake.

2. All of the affected populations of trout and suckers are non-native and have been introduced by the activities of man. The trout in each of these lakes are maintained by annual stocking.

3. The numbers of fish killed is not considered serious because only a very small proportion of the existing populations were thus affected. The indirect damage due to the killing of the aquatic insects and thereby reducing the food supply was not measured and is difficult to estimate.

4. The fish in the shallow water where they had more direct contact with the insecticide were more readily affected.

5. DDT in an oil mixture, even when applied in normal amounts, on or near the surface of lakes tends to accumulate in greater concentrations along wind swept shorelines through the action of the wind and waves. This concentrates the mixture so that it has a stronger toxic effect upon the fish especially in the shallower waters.

6. No apparent effects upon the birds or mammals of the Tuolumne Meadows-Tenaya Lake Area were observed as the result of the aerial spraying of the DDT.

7. A few frogs were apparently killed by the application of DDT although no other forms of amphibians or and reptiles were observed to have been killed or otherwise affected.

8. The total kill of insects was not measured or estimated. Water beetles, dragonflies, ants and bees were observed dead or dying. The effects upon the aquatic insects were not measured in the Yosemite observations but other studies have revealed that the application of DDT even in dosages of 1 pound per acre has resulted in very heavy mortality — as great as 90 percent. Fortunately, the recovery of these forms is reported to be relatively rapid; a near normal condition returning in about a year.

Recommendations for Consideration in Future DDT Spraying Operations in Yosemite National Park and in Other National Park Service Areas.

(Adapted from the recommendations of the U. S. Fish and Wildlife Service. Circular 15. Linkuska & Surber: 1948)

1. Use DDT for the control of an insect pest only after weighing the value of such control against the harm that will be done to beneficial forms or endangered native species of life. The widespread use of DDT in any National Park Service Area should receive the approval of the Director before each project in undertaken.

2. Use DDT only where it is needed, and in all cases use only the minimum quantity necessary for control. Wherever it is applied by airplane, provide careful plane-to-ground control to insure even coverage and to prevent local overdosages.

3. Avoid, as far as possible, direct applications to streams, lakes, and coastal bays because of the extreme sensitivity of fishes, crabs, and aquatic insects to DDT and because of the

tendency of DDT to accumulate in greater concentrations along shore areas due to wind and wave action.

4. In aerial applications, over aquatic areas, use one-fifth pound or less of DDT to an acre in oil solution to avoid damage to fishes, crabs, crayfishes and other aquatic inhabitants. If treatment is repeated several times in a season, use one-tenth pound to an acre or less. As a greater percentage of the applied dosage is deposited at the water surface by most ground methods of application, these dosages should be reduced by 50 percent when ground spray equipment is used.

5. In forest areas use less than 2 pounds of DDT to an acre to avoid damage to birds, amphibians, and mammals. Because of its great toxicity to many aquatic forms, use smaller quantities of DDT in emulsions.

6. Wherever DDT is used, careful before and after observations of the effects of the applications upon the mammals, birds, fishes, and other wildlife should be made. A report covering these observations should be forwarded to the Director's Office through the Regional Office.

7. In the control of early appearing insect pests, apply DDT, if possible, just before the emergence of leaves and the main spring migration of birds; for late appearing pests, delay applications whenever practicable, pas the nesting period of birds.

Literature Cited

Adams, Lowell, Mitchell G. Hanavan, Neil W. Hosley, and David W. Johnston.
1949. The effects on fish, birds and mammals of DDT used in the control of forest insects in Idaho and Wyoming. Journ. Wildl. Mgt. 13:3; pp. 245-254.

Brown, A. W. A.
1951. Insect control by chemicals. New York: John Wiley and Sons Inc. pp. 817.

Cottam, Clarence and Elmer Higgins
1946. DDT: Its effect on fish and Wildlife. Fish & Wildlife Service Circular 11, pp. 1-14. Washington, D. C.: USGPO.

Linduska, J. P.
1950. DDT: Its effect on beneficial life. Garden Club of America. Bull. 38:1 (Jan.) pp. 76-82.

Linduska, Joseph P. and Eugene W. Surber
1948. Effects of DDT and other insecticides on Fish and Wildlife, Summary of investigations during 1947. Fish and Wildlife Service Circular 15. pp. 1-19. Washington, D. C.:USGPO.